THE ABUSE OF

THE STEAM JACKET

PRACTICALLY CONSIDERED

With a Statement of some of the requirements for obtaining beneficial results,

BY

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WITH ILLUSTRATIONS.

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THIS WORK

IS RESPECTFULLY DEDICATED

TO ALL

WHO ARE ENTRUSTED WITH THE DESIGNING—
MANUFACTURE—ERECTION OR DRIVING OF

THE STEAM ENGINE

BY

THEIR OBEDIENT SERVANT,

THE AUTHOR.

PREFACE.

The ORIGIN of this little book may soon be told.

Some two years ago I purposed writing a letter to one of our Engineering Journals on the Steam Jacket, in reply to a correspondent who sought information on the subject, for which object at considerable trouble (for the literature of this subject is most meagre) I collected a tolerably large amount of information, but owing to the time devoted to the search, I was led to relinquish the idea of the letter, but continued the study with a view at some distant date of writing a Treatise on the Steam Jacket, this idea is now being carried out, the "Complete Treatise on Steam Jacketing," is in active preparation, and while busily engaged with this work, I was astonished to find that very little or

nothing had been said respecting the misapplication of the Steam Jacket, or Its Abuse as I have termed it, notwithstanding that in practice the utility of about four out of every six Jackets that I have examined was very much impaired, if not wholly destroyed, occasioned by their imperfection; which accounts for the appearance of this little treatise, wherein I have sought not only to point out the defects in many steam jackets in use to-day, but also to lay down some principles relating to their proper design and application, and seeing that this book furnishes the only information on this neglected subject, I trust that the contents may prove of some service to designers and makers of steam engines.

I may mention here, that the fact of the scarcity of Engineering books written by practical men* has served as an incentive to energy, and caused me to hope that this first literary venture, emanating from the drawing office and works, may, (irrespective of its faults) meet with some measure of support and approval.

* Well written, practical books, from the pens of competent practical men, are as scarce, and nearly as valuable as gold. "The Engineer," 17th May, 1872.

Our cleverest engineers and those most competent to write good practical books which would be of permanent value to the rising generation of engineers, are so busily engaged in the manufacture of engines, that they have not the time to write about them, for the very reason that the manufacture of engines is a far more profitable undertaking than the production of books relating to engines.

In many engineering books, the efforts of the authors are spread over such a large surface, that the information given is too superficial to be of any real value: where a few lines are devoted to the explanation of each detail of the steam engine for instance, in all probability those few lines will fail to supply the information needed, and serve no good purpose to the enquiring mind. Who does not remember reading numerous books of this class in the hope of finding some valuable notes, and after wading through the contents have had to close them in disappointment?

Take, for illustration, the valuable detail we are studying—the steam jacket. In many works on the steam engine it is not even mentioned, in some, two or

three paragraphs only are devoted to its consideration, and those few who have written more lengthily have treated it, like many more engineering subjects, in a theoretical style, so that the literature is adapted for students only, and is perfectly useless in the workshop, and in the majority of cases of very little real service in the drawing office.

If authors would confine themselves to the study of one detail and thoroughly ventilate it, their remarks could not fail to be of practical service, indeed this is just the style of book relating to the steam engine of which there is the greatest need.

It may be owing to this dearth of literature in a great measure, that accounts for such widespread ignorance respecting the use of the steam jacket prevailing among engineers. It is to many a perplexing paradox, when engine-makers who do *not* apply it, evidence some hazy notions respecting its utility, we are not surprised: but when we find engineers at the head of one of our largest portable engine firms (who profess to have jacketed their earliest engines and still continue the practice) saying, that the cylinder is protected from "*cold* and

radiation," by means of a jacket of steam, clearly shewing that the function of the steam jacket is not understood by the writers, we are a little surprised, and can only excuse them on the ground above named, viz. the fragmentary nature of the information relating to this subject. One writer says:—"Almost every engineer knows now-a-days that a cylinder should be kept as hot as possible; but very few makers of steam engines understand the precise reasons why a cylinder should be kept hot. Most people imagine that the condensation takes place by conduction through the metal of the cylinder to the outside."

As a consequence of the prevalence of these mistaken notions it follows that very little if any good has resulted from the voluminous discussions on Steam Jacketing. In my opinion the practical conclusion of the whole matter appears to be:—*The fact of the utility of the steam jacket when properly applied cannot be gainsaid,* but owing to numerous cases of internal malarrangement, its efficiency is impaired or destroyed, occasioning in some quarters a doubt respecting its advantage.

Some portions of the contents of this book have already appeared in the pages of "Engineering," see my letters on the Abuse of the Steam Jacket in that Journal for August 3rd, September 28th, and November 9th, 1877—the illustrations are reproduced from the same paper prepared from the sketches I supplied with the letters.

As far as practicable I have acknowledged the source from whence I have drawn extracts at the foot of the page where the passages occur—"Hopkinson's Engineer's Guide," "Northcott's Theory and Action of the Steam Engine," and particularly some valuable and suggestive articles in "Engineering" and "The Engineer" have proved serviceable.

W. FLETCHER.

WORTING ROAD, BASINGSTOKE,
26th February, 1878.

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INTRODUCTION.

The following are Mr. WATT's own words concerning this admirable invention.—"My method of lessening the consumption of steam, and consequently fuel in fire engines, consists in the following principles:—First, that the vessel in which the powers of steam are to be employed to work the engine, which is called the cylinder, and which I call the steam vessel, must, during the whole time the engine is at work, be kept as hot as the steam which enters it; first, by enclosing it in a case of wood—secondly by surrounding it with steam." Specification of Patent, 1769.

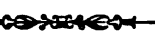
THE Steam Jacket has been in use just a century, it was invented by the illustrious Watt; he introduced it about the same time as the separate condenser: the Steam Jacket and the Condenser were his first improvements, they being the principal means employed by him for reducing the enormous waste of steam that took place in the engines of his day, owing to the cylinders being continually cooled by sending the injection water directly into them.

Although Watt left the steam jacket very much the same as we have it now, yet there have been numerous Patents taken out relating to its improvement, in the period that has elapsed since his time; it is not our intention at present to notice these propositions, suffice it to say that some few of them contained suggested improvements, most of them however propose useless alterations, or impossible devices.

During these one hundred years of the steam jacket's history, it has been the subject of conflicting opinions;—at one time it has enjoyed a very meagre amount of favour, it only being applied to engines of one class;—during another dispensation it has been the rule to steam jacket almost all engines;—while at another period it has been nearly abandoned altogether;—in spite of all these changes of public opinion, the steam jacket has not only held its own, but has gained ground, for it ranks among the economising improvements of modern steam engines, and is now more universally applied than ever it was.

Not only was its utility often called in question, but many plans were, during its history, suggested for effecting the same ends by other means, such as surrounding the cylinder with

heated oil, wax, or a solution of potash and water, with a layer of tallow on the surface; by circulating the hot gases around it before they escape into the chimney; by keeping a separate fire underneath it, &c., not one of these proposals however has been successfully applied. It is self evident from the specifications, that the true function of the steam jacket was very imperfectly understood by many inventors, in fact the major portion of the plans intended for heating the cylinder, &c. are the outcome of the grossest ignorance of the laws of heat. For instance, the absurd notion of keeping the outside of the cylinder at the same temperature as the inside by means of the comparatively cool exhaust, has been embodied with several patents, while it is mentioned in numerous specifications, in one case as recently as 1862.*



The Function of the Steam Jacket

is to prevent the liquefaction of steam within the working cylinder during admission and expan-

* The practice of jacketing with exhaust steam is happily now almost entirely abandoned, and it is surprising that any one should have expected that cold steam would give up heat to warmer steam. p. 37, "Economy in the Use of Steam," by F. Salter.

sion, which condensation represents a loss of heat, and waste of energy; for when the jacket is used, the sides of the cylinder being hotter than the incoming steam, no condensation will take place while the steam is being admitted; and during expansion the liquefaction of steam due to the performance of work cannot take place within the cylinder, but is transferred to the steam within the jacket, where the presence of water produces no bad effect, and may be at once returned to the boiler, "where it is re-evaporated, and flows to the cylinder to do more work; whereas, if the liquefaction had taken place within the cylinder, the resulting water would have been re-evaporated there instead of within the boiler, and the resulting steam, although obtained at just the same expenditure of power, would, instead of doing work on the piston, do it in heating the condensing water" or be lost during the exhaust.* The Editor of

* Thus, without steam jackets, a large quantity of steam passes through the cylinder in the form of water without doing work; whereas if the cylinder is steam jacketed no condensation takes place, and the whole of the steam does its full duty according to the degree to which it is expanded. Indeed, without steam jackets, or hot air jackets, or other means of keeping up the temperature of the cylinder, it acts to some extent as a condenser at the beginning and as a boiler at the end of the stroke. "Cyclopædia of Useful Arts, vol. 3." Mr. A. E. Cowper, Art. Steam Engine.

"The Engineer," says "one of the great points gained by the jacket is the presence of nothing but dry steam at all times in the cylinder."

Mr. A. Mallet says:—the true statement of the action of jackets is: "that they maintain the heat in the cylinder and cause condensation to take place in the jacket where the pressure is constant, and not in the cylinder where it is variable." "It follows, as a consequence, that the condensation which takes place in the jacket does not in any way represent loss of fuel."* Another writer says:—"The jacket is to the full as elegant a device as the separate condenser; and, when applied in the best possible manner, it is as capable of transferring the performance of all work done to itself, as the condenser is of taking the work of condensation to itself."

Out of the other means which have been recommended for preventing the condensation of steam within the cylinder, the only two which have been carried into practice, are

Superheating the Steam, and the use of Hot Air Jackets.

The former is now very little, if at all used

* "The Engineer" for November 17th, 1871.

except for Marine Engines, and then it is carried to a very moderate extent, that it is doubtful whether the temperature of the steam is raised sufficiently to prevent condensation. The Super-heating Apparatus is expensive, cumbersome, and very liable to get out of order; and by the least amount of neglect, the steam may be so much overheated as to seriously injure the internal working surfaces of the engine. The following remark concerning this subject, is quoted from "The Engineer" for 18th February, 1870. "The Super-heater, constitutes a member of the theoretical perfect engine and above all others, the most liable to get out of order itself, and to induce mischief," and in another place in the same journal it is stated, that "the cost of the superheating apparatus, and the excessive wear and tear to which it is subjected, constitute almost insurmountable obstacles to its general adoption."

The grave objections to the use of Super-heaters, also apply to the use of Hot Air Jackets; the same *over-dryness* of the steam is experienced when these are applied, attended with the consequent evils—it hardens the packing—counteracts the lubricants in the cylinder,

and causes the slides, pistons, &c. to be rapidly worn away. Hot Air Jackets are now very rarely used.

In Messrs. Clayton and Shuttleworth's Patent Portable Engines, the cylinder is placed within the smoke-box, but is also steam jacketed as well: this combination effectually preventing the hot gases from causing any inconveniences by super-heating the working steam.

Mr. Rankine says, "that by enclosing the cylinders within the smoke-box, as is done in many Locomotive Engines, there is not the same security against over-dryness of the packing, that there is with the steam jacket."

Mr. Northcott in the Theory and Action of The Steam Engine, says "there are practical difficulties in using the hot gases in the jacket, chiefly arising from their high temperature, and from the deposit of soot and tarry matter upon the surfaces of the jacket. The former leads to excessive friction in the cylinder, and the latter to the choking of the passages, and the non-transfer of heat."

The internal condensation caused by the performance of work, &c. within the cylinder, can only be successfully minimised by the applica-

tion of the Steam Jacket; a device, unlike all other schemes for effecting the same purpose, is most easily applied—of trifling cost—simple—and not at all likely to get out of order if properly designed.

There are still to be found some few engineers however, who call in question the benefit to be derived from the use of the steam jacket, and by the aid of figures, and repaired indicator diagrams, they prove to their own satisfaction the truth of their opinion: but very little dependence can be placed on the results arrived at by theoretical investigations, this being unfortunately one of those questions where figures may be made to represent almost anything the theorist pleases.

It is by accurate experiment alone, that all problems of this class can be satisfactorily solved.

Watt did not ascertain the utility of the steam jacket by figures, but by actual test, and strange to say the very first theory that we read of, which was raised against its use, viz. Tredgold's, proved to be incorrect. Tredgold hastily and erroneously concluded that the jacket was only used to prevent the radiation of the working

steam; and that, "although it did this, it did it by the waste of more steam than would have been wasted in the unjacketed cylinder, the excess being, in Tredgold's judgment, that due to the extra size of the jacket over and above that of the cylinder which it enveloped."*

Neither is Tredgold's error yet exploded, for many engineers speak of the steam jacket as though its duty consisted entirely in preventing the radiation of the working steam—they confound the work which the clothing performs, with the work which the jacket performs—it must be distinctly understood that the two duties are widely separated.

It will be found that in many instances when the utility of the steam jacket is called in question, its function is very imperfectly understood; for instance, how often we hear the hackneyed phrase respecting the use of the steam jacket, "that the loss from radiation may just as well come from the steam in the cylinder as from the steam in the jacket," whereas the loss in unjacketed cylinders is not measured by the radiation at all, but is a much greater loss

* Messrs. Bramwell and Easton's report on the Wolverhampton Trials, 1871. "Journal of the Royal Agricultural Society."

as we have already explained, in the paragraph on the Function of the Steam Jacket.

Practical Proof of the Efficiency of the Steam Jacket.

It would be an easy matter to fill pages with instances of engines fitted with steam jacketed cylinders, in which, the jacket steam having either by accident, or for experiment been turned off for a short time, it has been necessary in order to maintain the speed, to alter the expansion valve, to give a later cut off: and the boilers have had to be fired harder to keep up the steam; although these cases prove the advantage of jacketing, yet the writer has taken pains to collect the records of numerous experiments, accurately carried out by different engineers, on all classes of engines: and these results invariably prove beyond doubt, the importance and economy of steam jacketing.* For practice proves that the jacket is valuable, wherever it has been properly applied and properly tested.

* It is proposed to publish those records in a Treatise on Steam Jacketing now in preparation.

Mr. John Bourne, in his well known work, entitled "Catechism of the Steam Engine," says:—"It appears to be indispensable to the realization of any large amount of benefit by expansion, that the cylinder *should be enclosed in a steam jacket*, or should in some other way be effectually protected from refrigeration. In some engines *not so protected*, it has been found experimentally, that less benefit was obtained from the fuel by working expansively than by working without expansion. In Cornwall, where great attention is paid to economy of fuel, all the engines are made with steam jackets. Mr. Watt in his early practice discarded the steam jacket for a time, but resumed it again as he found its discontinuance occasioned a perceptible waste of fuel; and in modern engines it has been found that where a jacket is used, less coal is consumed than where the use of a jacket is rejected."

A correspondent in "The Engineer," writes as follows:—"My experience of 25 years in designing, building, and working expansive engines, has convinced me that the steam jacket is a great economiser when used under such a condition and in such a position with respect to

the boiler, that it contains and is supplied with dry steam, so that all water resulting from condensation within the jacket can be returned to the water space of the boiler, without further loss of heat."

One writer says:—"Now it has been proved to demonstration that Steam Jackets promote economy of fuel, nay, that without them economy in the true sense of the term is an impossible thing."

Another great authority says:—"We know now that we cannot work with the expansive engines to any good purpose without a steam jacket."*

Another writer says:—"There can be no possible doubt respecting the benefit to be derived from steam jacketing."

I am of opinion, that had all jackets been properly designed and applied, their utility would before now have been universally acknowledged, and no engine would be considered first-class unless it were steam-jacketed. "An unjacketed engine bears very nearly the same relation to a jacketed engine that the first

* Lectures on The Steam Engine by F. J. Bramwell, Esq.

machines of Newcomen or Smeaton did to the best engines Watt ever built."

Notwithstanding the utility of the steam jacket when properly applied it is however by carelessness soon rendered not only ineffective but positively detrimental. Mr. Northcott says: "that the steam jacket may be quite ineffectual, or somewhat worse than ineffectual, if without the means of removing air and water from it."

There are numerous means whereby the economising influence of the Steam Jacket may be counteracted or destroyed arising from

1.—Faulty Designing.

2.—Defective Construction.

3.—Inattention on the part of the Engine Driver.

We will now proceed to shew how the steam jacket may be rendered of no use by careless designing, giving four illustrations of sections of cylinders taken from practice which are considered to be faulty in design.

THE STEAM JACKET

Abused by Faulty Designing.

The Steam Jacket to a cylinder is a static economiser. It has no working parts, does not move, and, if properly made at first, will never cost one farthing for repairs or renewal. "The Engineer," 14th January, 1870.

The Steam Jacket constitutes, a very important and valuable detail, of the Steam Engine: yet in its design, and construction, it has not received a tithe of the attention, that other parts of equal, or less importance have; consequently, it is, in far too many instances, little better than a sham, and serves to exhibit the carelessness, or ignorance of the designer. Now a defect in the design, of any other part of an engine, would very likely be quickly detected, or it may by its imperfect action, cripple the engine; but a badly designed steam

jacket, may work untold mischief undiscovered for years; it may be that the dainage is faulty, and the jacket is acting as a surface condenser: thereby aggravating to an alarming extent, the very evil it was intended to diminish. When I remember the numerous abortive steam jackets that have come under my notice during the last few years, I am at no loss to account for the opinions of engineers, respecting the utility of the jacket, being so diametrically opposed. Many of the people who denounce the Steam Jacket are those who being ignorant of its function, are unable to design it properly, and they have, evidently tested engines, which have had so called *steam* jackets applied, that were in reality, water jackets, acting as small condensers, or otherwise, and the unsatisfactory results obtained, have not of course influenced them to alter their creed.

It is somewhat surprising, that there should be any engineers left, who do not understand the requirements of efficient steam jacketing: but, judging by the number of defective jackets, (which cannot be of much, if any service at all,) that are continually being turned out, I am driven to the conclusion, *that there are many*

engine-builders still, who are totally ignorant of these essentials. The notion these people evidently cherish, concerning the steam jacket, is, that it is, simply a ring round, or partly round, the cylinder into which the steam is conveyed; it being quite immaterial whereabouts in this ring, the steam is taken in, or from whence it is drawn. The Editor of "Engineering" some time ago very wisely remarked:—"that to secure the advantages of steam jacketing, it is not sufficient to merely place around the cylinder a casing that *may* contain steam, care must be taken that this jacket always *does* contain steam.

Few but those who have actually tried it, fully appreciate how soon a jacket may be rendered ineffective by the accumulation of air or water."

No one who has given the slightest attention to this subject, can have failed to notice, that notwithstanding the many cylinders which are said to be jacketed: how very few, are really steam jacketed, thoroughly, and efficiently.

Mr. M. D. Stapfer in a paper on Steam Jackets, read before the Scientific Industrial Society of Marseilles says:—that there are "few

engines which have not their jackets partly obstructed." Practical experience confirms the truth of this statement, as will be gathered from the instances of careless jacketing which have come under the writer's notice, now to be recorded; these examples of miserable designing, have mostly been detected in the repairing shop: no more favourable opportunity can be secured for detecting the weak points in the design and construction of engines, than while they are undergoing repairs.

The most prevalent cause of the Steam Jacket's inefficiency, arises from the drainage being either altogether neglected, or badly carried out. Now most people readily admit, that the jackets of horizontal fixed engines, are often imperfectly drained, but they fancy that such cannot be the case, where the cylinder is bolted on to the top of the boiler, as in all portable, and most traction engines; but I have met with several cases of badly drained jackets, among this class of engine. Indeed the worst instance of careless designing of this sort, that ever came under my notice was found a few months ago, on a traction engine which was being repaired.

The following instance furnishes an example of a badly drained portable engine cylinder.

About three years ago some repairs were being done to a ten-horse power expansive portable engine made by a celebrated firm.

The cylinder and covers were jacketed, the lids being supplied with steam from the circumferential jacket by means of three or four holes drilled through the end of the cylinder; and opposite these, similar holes were provided in the covers. After removing these lids I found all the holes in each one filled, nay, I may say plugged up with red lead one inch thick, for evidently every time the cover joints had been made a fresh layer was added in each hole, to account for the thickness of lead named; after clearing out the holes which was no easy matter, as the lead was rammed in very tightly, and hard, I saw that the jackets of the covers were *full of water*, and judging from appearances they had been in this state for years; it is almost needless to remark that this is a very poor plan for supplying jacketed covers with steam. But this is not all, for when the holes were being cleared out in the ends of the cylinder, it was discovered that the circumferential jacket also,

was *half full of water:* the drainage of this steam jacket, had been entirely overlooked by the designer, for it was impossible to prevent the accumulation of water in it, without altering the arrangement considerably.

For the purpose of clearly showing, how the Steam Jacket may be abused by incompetent designing; I have placed before me, drawings of sections of a dozen cylinders, of modern portable, traction, horizontal, and vertical engines: some traced from recent published drawings, others taken from practice, and by noting their defects, the way will be paved for others to test their jacket drawings, and ascertain whether they are arranged, so as to insure perfect success.

Out of the twelve examples chosen, in eight of them, the jacket is only carried partly round the cylinder; in some cases, only two thirds round it, while a great part of the cylinder body is exposed to the exhaust steam. See figure 1 for an illustration of this.

Portable Engine Cylinder.

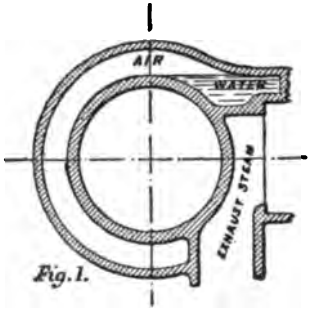


Fig. 1.

Portable Engine Cylinder.

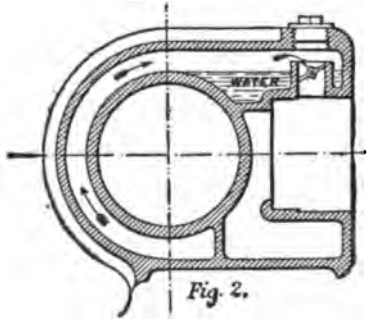


Fig. 2.

Traction Engine Cylinder.

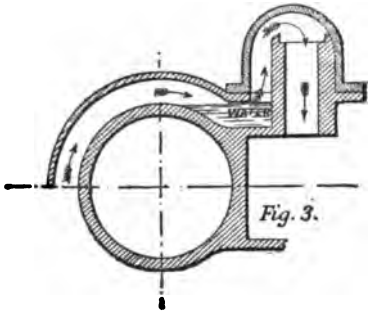


Fig. 3.

Horizontal Fixed Engine Cylinder.

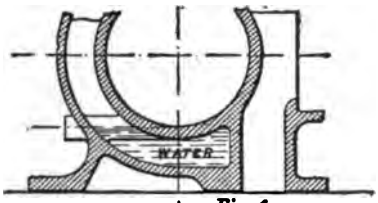


Fig. 4.

In six cases, the working steam is made to enter the jacket space, and traverse round the body of the cylinder on its way to the valve-chest; a practice which in the Cornish Engine

has been abandoned,* and should be rejected in all engines, seeing that the steam is robbed of its heat, and condensed, before it reaches the cylinder, the water resulting from this refrigeration, being carried with the steam into the cylinder. Figures 2 and 3 are illustrations of this class. The jacket may be said, to "drain itself through the cylinder."

Mr. Northcott in "The Theory and Action of the Steam Engine" page 108 says:—"In all cases the jacket should be distinct from the cylinder, as when the steam is passed through a jacket on its way to the cylinder, the water condensed in the jacket is carried with the steam into the cylinder, and the result is much the same as would be produced without the jacket."

In two examples, no provision has been made for obtaining a thorough circulation of the steam within the jacket, or for expelling the air, see Figure 1. The following incident which occurred at a trial of portable engines, seems to

* In the earlier Cornish jacketed engines the steam for the engine was taken from the steam jacket, but the plan has subsequently been abandoned, and the steam pipe is now always made to lead direct from the boilers to the top nozzle.

prove that air does sometimes accumulate at the highest point of the jacket, and prevent its becoming heated by the steam, notwithstanding that some would tell us, that such cannot be the case.

A correspondent in "Engineering" says:—"The cylinder of one engine was steam jacketed, being on the top of the boiler the admission of the steam was direct to the jacket; it might be supposed that the jacket would be heated as the steam rose, the jacket felt quite cold with sixty pounds pressure of steam in the boiler, until the safety valve (which was on the top of the cylinder, in communication with the jacket) being eased a little, a current was formed in the steam, shewing clearly that the air must be expelled before they can be heated properly."

In seven cases, the drainage is very imperfectly carried out, in numerous instances it is entirely overlooked, even when the jacket happens to be drained at the bottom, which in all portable engines it is not; there is generally some shelf or partition at the top, where water may be stored away. Figures 1, 2, and 3 illustrate these cases.

In figure 2 for instance, the steam is made to pass round the cylinder body over water to reach the steam chest; this water lying in contact with the cylinder wall tends to waste the heat of the working steam, and causes other evils on the top of the jacket, while a large area of the side of the cylinder body, is in contact with the cooling influences of the exhaust steam.

But Figure 3 represents a worse case still, for not only is the working steam made to traverse round the cylinder, but it must, before it reaches the stop valve, either pass through a body of water, or carry some of it with it into the cylinder. Figure 4 represents an example wherein the bottom of the jacket will *always contain some water*, because the jacket drain cock is in a line with the cylinder drip cocks, several inches above the bottom of the jacket, the levers of the three cocks being coupled together; not only so, but the fact of the drain cock being connected to the drip cocks, shews that the condensed steam will never be blown out except when the cylinder cocks are opened: and the attendant may only do this two or three times a day, which is not nearly often enough, as the water within the jacket, should be got

rid of as quickly as it is formed: hence, the injurious effects occasioned by such an improper arrangement will be apparent to all; for it is more than probable that the jacket will often be full of water.

In two cylinders, the steam for the jacket is actually drawn from the valve-chest, while the supply pipe for one of these jackets, is also made to pass through the exhaust steam chamber. In many large horizontal fixed engines the jacket supply pipe is much too small; in one case it was only $\frac{3}{4}$ of an inch dia. for a jacket round a 16-inch cylinder; it is somewhat questionable whether the jacket pressure would equal the boiler pressure by two or three pounds per square inch.

In two instances only are the lids jacketed; in one of these, they are so badly supplied and drained that they will be generally choked with water; while in the other case (a vertical engine cylinder,) both covers are well supplied with steam, but the top cover will always have a film of water $\frac{1}{4}$ of an inch thick spread over the bottom face of the cover, which should have

been of service to the working steam, but owing to the drainage being most ineffective, this top cover will instead exert a powerful influence for evil on every admission of steam.

There are other minor evils caused by faulty designing, but enough has been said to show the necessity for an alteration in some of the cylinder drawings of modern engines.

THE STEAM JACKET

Abused by Defective Construction.

Let us see how the steam jacket may be abused by mal-construction.

It has been my lot to have had (in addition to the designing, &c., of new engines,) the superintendence of repairs to numerous portable, traction, and other engines for the last five or six years, during which time, I have had a favorable opportunity for noticing the weak points in the construction of the engines of different makers; and it would be an easy matter to place on record the description of some very curious steam jackets that have during this time been discovered; but such a catalogue of makeshifts and mistakes would not answer any good purpose were they recorded. I have chosen out of a great number, three cases under this head, to shew how bad workmanship

may interfere with or destroy the utility of the jacket; the first is the record of a cylinder having a flaw in it, attributable to incompetent moulding—the second case is the result of carelessness during the erection of an engine—while the third, is an account of a badly turned and bored cylinder liner and jacket, which were made in separate castings, and when put together, being a very indifferent fit, did not constitute a tight joint between the two when tested under steam.

It is well known by practical men, that there is considerable difficulty in procuring a sound casting from the foundry of a cylinder when cast with a steam jacket round it: hence, to reduce this risk the walls of the cylinder are made excessively thick, some makers of portable engines use a cast iron wall of quite an inch thick for a cylinder but 9-inch bore. We need not be surprised to learn, that these users of thick cylinder walls, are somewhat disappointed in the results arrived at during the use of such jackets: for it has often been affirmed that these thick walls, seriously interfere with the efficiency of the steam jacket.

"The Engineer" says:—that "the steam jacket is useless, if the walls of the cylinder are so thick, that heat cannot be freely transmitted from the steam outside to the steam inside—the fault lies not in the jacket, but in the manner of making it; we must not condemn steam jackets however because of incompetent moulders." In cases where the jacket and the cylinder are cast together and the walls and partitions are of varying thicknesses, and particularly when there are any lumps of metal left in corners and other parts of the cylinder, the partitions are very likely to be "spongy," caused by the "drawing" of the metal during cooling; in some instances, a place of this sort is not detected until the engine is tried, or has been at work some time, when the flaw has commenced to leak steam from one part of the cylinder to another: sometimes blowing from the jacket into the steam chest, or the supply ports, which of course, seriously interferes with the working of the engine. The only remedy in this case, and the one very often resorted to, is to cut off the steam supply from the boiler to the jacket. Here is the record of a troublesome steam jacketed cylinder of this

description being doctored, which I heard from the lips of the facetious party who effected the "cure," as he was pleased to call it; and, as I entertain not a doubt respecting the accuracy of the story, it will serve as a case in point for this part of the subject. A new eight-horse portable engine, made by a small firm, was sent out to a customer, having a faulty place in one of the walls of the cylinder between the steam jacket and the slide valve-chest, which had either not leaked during the trial on the works, or it had not been discovered; but unfortunately, very soon after the engine was put to work, it began leaking so rapidly that it was impossible to stop the engine when required, as there was provided no means of shutting off the steam from the jacket round the cylinder.

Complaints were at once despatched to the makers, who sent out a fitter "to look to the stop valve gear," and ascertain the cause of the annoyance, and put the engine to rights; he soon found out that the stop valve gear was in order, and that the steam gained access to the valves above the stop valve through this faulty place in the cylinder partition.

After dropping the steam, taking off the steam-chest cover, and convincing himself that no patch could be put over the flaw, an idea (of which he is ever proud) at once suggested itself, and he took the cylinder off the boiler to put his happy thought into practice. Now the jacket of this cylinder was supplied with steam by means of a piece of one inch piping screwed through the arch plate of the boiler into the bottom of the jacket. By a little manœuvring he managed to take out this pipe from the inside without the engine driver, who was helping him, noticing the act; he then told this assistant that he had found out the cause of all the trouble, or to use his own words, "I have found out a 'mare's nest'," pointing to the hole through which the supply pipe had been screwed. "This hole has no business to be here, and must be stopped up"; his ignorant and confiding mate nodding assent.

He screwed and rivetted a plug into it, re-made the cylinder joint and the connexions, steamed the engine, pronounced her cured, then took his leave of the driver, who no doubt is just as satisfied with his engine with a "dummy" jacket round the cylinder as he was with a real

one, seeing that he has always been totally unaware of the jacket's existence, much less its use.

So long as this jacket *remains* as an air space, it would be of slight service in checking the radiation of heat from the working steam within the cylinder; but it is very probable that some of the steam finding its way through the flaw, from the valve-chest into this jacket space, would be condensed; in the course of time, therefore, the water resulting from this condensation would fill the jacket up to the level of the flaw, there being no means of escape at the bottom. It is needless to mention that the jacket in this state, viz., half filled with water, instead of being of *slight* service, would be a positive evil.

Most of the jackets that are abused by incompetency, laziness, or carelessness, are rendered useless owing to the accumulation of water in them, the water jacket being by far the commonest type.

Here is the record of another type of jacket. The outside casing around one of the cylinders of a double portable engine, by another maker, was accidently cracked during the erection of

the engine, (cracked cylinders are evidently not solely confined to the engines of Her Majesty's Navy,) and as a patch could not be put on the outside, because the cylinders of this firm are not arranged for lagging—lagging being an admirable cloak for hiding such like "bodges," notwithstanding its utility, the following plan was adopted in this dilemma; the jacket space was filled up and rammed with rust cement through the cores in the end, and the pipe for supplying the jacket of this cylinder was like the one in the last case, plugged up, to prevent the possibility of any steam leaking through the cement and out at the crack.

We have heard of hot air jackets, smoke jackets, water jackets, exhaust jackets, and steam jackets, but this is a novel one, viz., a cement jacket, a makeshift truly of doubtful utility.

Another instance of a leakage from the jacket to the cylinder, of rather a different nature, occurred on a large horizontal fixed engine made by a very small firm—the cylinder and bush were separate castings, the latter turned, and the former bored to suit, but owing to incompetency, or great carelessness on the part of the

turner: the joint leaked all round after the bush was inserted when under steam—the cylinder was then put under a rusting process, or to use the workmen's term it was "pickled" in sal-ammoniac and water for some days: but all to no purpose, for when steamed again it leaked into the cylinder at each end. The engine was, I am told, sent away in this plight, for unfortunately no diagrams were taken, so that this carelessness was not revealed to those who might have condemned such mal-construction, and prevented the engine being sent away in this manner.

THE STEAM JACKET

Abused by Inattention on the part of the Engine Driver.

The Steam Jacket may be abused by carelessness on the part of the attendant, whenever its right action depends on his control. In large engines of one or two types, the condensed steam from the jackets is generally carried away by means of a pipe having a cock in it, placed within the reach and under the control of the engine-driver, which is an unsatisfactory arrangement, because the chances are that the cock may not be opened at all, or not nearly often enough, an ignorant driver thus having it in his power to transform an efficient jacket into an efficient condenser, the result causing an enormous waste. It is very essential that the supply and drain pipes for the jackets should

be so arranged that it is quite unnecessary for the engineer to interfere with them, or as some one recently put it, "quite independent of a lazy or careless engineer." It is equally important that the opening and closing of these pipes should not be left to the discretion of the attendant, because of his love of meddling with, and experimenting upon, every detail of the engine under his charge; for in these individuals, as in most other mechanics, where there is a minimum supply of knowledge, there is generally to be found a maximum amount of conceit, and no sooner is an engine placed under their charge, than they find out a number of imaginary defects and details requiring improvement; this tampering with the engines very often ending in disaster.*

* Since writing the above remarks respecting the omission of duty by the engine-driver, and the delight he generally evinces for trying his hand at the improvement of parts, &c. causing Steam Jackets either to be neglected altogether, or else shut off, I have read Mr. Bramwell's two excellent lectures on "The Steam Engine." Macmillan, 1877, wherein he mentions the engine-driver's power in many cases to frustrate the designer's intentions, and consequently to waste his employer's fuel. Here is the sentence referred to:—"I do not think that the economy of the compound engine really lies in its principle, but that its economy in practice arises from another thing altogether, and that is this, that by making a double cylinder engine you put it out of the power of an ignorant engine-driver to do away with that

The following is an amusing instance illustrating this trait in their character, given in a little book entitled, "The Engine Room, Who should be in it, &c." by an Old Hand, which we quote, although it is a slight digression.

"When at Galatz in 1867, a boat was sent from the I—, of N—, with a request from her captain to ours to allow me to go on board of her, as they could not start the engines; our captain being agreeable, I went. On getting on board the captain introduced me to the engine room, where, in the faces of all was a look of half bewilderment. The captain, being a true representative of the north country vernacular, said to the chief 'Winna she gan yet, what's wrang wi' her?' 'She's a' het' says the chief.' 'Dinna ye think the improvement hes out te de wi't?' says the captain. 'Na, na,' says the chief, 'it hes nout te de wi't, she's fu' o' san.' During this colloquy the reversing wheel was turned repeatedly, but to no purpose. I asked the captain what improvement he alluded to; he told me that his engineer had got some undefined notion from the engineer of another steamer, that the only way to save his coals was to 'gie her sma' steam,' and that he had done something 'wi' the slides,' but what

which you want—high expansion; he must get high expansion; he is compelled to use it whether he likes it or not, whereas with the single cylinder expansive engine he has the power to follow the dictates of his own ignorance, and as a matter of observation I have hardly ever seen such an engine left to the control of an engine-driver but it invariably worked at the lowest possible grade, and as I have said, I believe that this withdrawal of control is to a large extent the secret of the success of the compound cylinder engine.

that was he could not say. It was proposed by the captain, at my suggestion, to lift the casing cover. What a look of offended dignity the chief assumed! Much against his will the steam was blown off, &c. &c., and the cover lifted, when the reason of the engines not starting was at once apparent. Three quarters of an inch of wrought iron had been pinned (and very badly) on to the ends of each slide valve. I asked the chief if he had done anything with the eccentrics, 'Dune out wi't sheaves? Na, na, they're a' reet.' The economical pieces were taken off, and she proceeded the following day. I learnt this chief was 'a converted fireman.'"

The following paragraph is quoted from a letter signed A. M. in "Engineering," for 10th April, 1874. "Those engineers who advocate the disuse of steam jackets do it merely to save trouble to themselves, never thinking of the amount of money they cost their owners, so long as the engine gives no bother, a few revolutions is nothing to them. I heard of an amusing instance the other day of an engineer, when asked as to his steam jackets, he coolly answered that they were shut off to keep the engine room cooler; and of another, when the maker of the engines visited the engine room, he found the jacket space filled with water doing the duty of a condenser on a small scale. The maker of the engines put the question. Of what use is my

spending so much money on steam jacketing when owners will not see the intention carried out, although it is for their own benefit?"

In the foregoing sentences, I have attempted to show that a large proportion of the jackets in use now are *steam* jackets only in name, owing to the accumulation of water, or air, or both in them, causing a reckless and enormous waste of steam power, for it is needless to add that steam jackets abused in the manner we have indicated, are worse than none at all.

It would be infinitely better for all, particularly buyers, and far more creditable to us, as a profession, if makers of low priced engines (who are not competent to design good engines with efficient steam jacketed cylinders) would confine themselves to the production of that class of engine only which have unjacketed cylinders, instead of attempting to imitate higher productions, then we should probably have fewer cases of deplorable and abortive jacketing to record.

Some Requirements of
EFFICIENT STEAM JACKETING.

I have pointed out the manner in which the steam jacket has been rendered of little or no value on account of faulty designing, defective construction, and inattention. It would seem judging by past experience that *incompetent designing* is by far the most common cause of the inefficiency of the steam jacket. If any one will take the trouble to examine the steam jacket on various classes of engines he will find more examples of wretched scheming than could be found connected with any other detail of the steam engine. From this it is self-evident that the requirements of efficient jacketing are rarely understood, but this ignorance may be partly accounted for from the fact, that little or nothing has been written on this part of our subject—

the steam jacket has been mentioned by various writers on the steam engine—there has also been much written at various times respecting its utility—but very little has been said concerning the requirements necessary to render it of service, in other words no one has, to my knowledge, stated how the steam jacket should be arranged and applied.

In order therefore in some measure to supply this want, it may not be out of place to here note some of the chief points of importance which it is necessary should be strictly attended to both by Designers, Manufacturers, and Owners of steam jacketed cylinders in order to produce and keep them in efficient working condition so that the object for which they are applied, viz. the economy of fuel, may be fully realized.

As the greatest responsibility rests with the draughtsman, how very important it is that he should endeavour to thoroughly and conscientiously work out the details of engines, ever aiming at the highest results, remembering that every detail of machinery illustrates the mind, and to some extent the character of the designer; yes, to engineers these parts of engines express

more intelligibly than words can even, the designer's thoughtfulness and wisdom, or his haste and ignorance; the smallest detail unmistakeably exhibits every evidence of care that has been bestowed in the drawing office on its production. Let us all therefore aim at perfect efficiency and complete success.

> "'Tis not in mortals to command success;
> We will do more—deserve it."

By careful designing we may to a large extent perform our part of the "duty that devolves upon scientific mechanical men, viz. that of preventing the scandalous waste of fuel that now, alas, too frequently occurs."

The following may be mentioned as some of the leading principles of Efficient Steam Jacketing.

1. *The Jacket should completely encircle the cylinder from end to end.* In cylinders that have liners cast separately and inserted into the casing or jacket this point is fully and invariably carried out, as will be readily understood on referring to Figures 5 and 6, page 57.

But in a multitude of other cylinders which are cast entire, the jacket is only carried partly round, in some cases not half round, while the greater part of the remaining surface of the cylinder body is in contact with the exhaust steam; the exhaust in a few cases is made to travel partly round it. It should not be necessary for me to refer to that old absurdity "the exhaust jacket," yet some of our long established makers are using this very absurdity on a small scale. (Apparently these people pay little regard to modern practice, but being greatly attached to the notions of the "good old times," are determined to abide by them as long as possible.)

More steam is dissipated by this custom than some would suppose, and of course, the larger the area of the cylinder body thus cooled at every stroke, the larger the waste of the heat of the working steam inside the cylinder.

2. *The Jacket must be supplied with steam of the full boiler pressure, that is, there should always be steam in the jacket as high as the highest steam within the cylinder;* it has, in fact, "often been proposed in large engines to jacket

cylinders with steam from a special boiler kept at a high pressure;" for instance, in 1854, Martini obtained a provisional protection for an improvement consisting in surrounding the cylinder with steam of about two atmospheres higher than the steam used to work the engine, the steam for the jacket to be generated in a small strong separate boiler.* I am not aware that this proposition has ever been carried into effect; but super-heated steam has been used in jackets.

3. *The Jacket should be open to the boiler at all times, and not affected by the stop valve, it will thus be heated gradually as the steam is raised, and always hot ready for work*; therefore no steam will be required and wasted by blowing through the cylinder for warming it. In small engines it is not necessary to provide any means for shutting off the steam from the jacket, but large engines are generally fitted, so that the steam may be turned off; care, however,

* "In Hopkinson's Engineer's Guide" the following sentence occurs at page 334. It is clear then that to secure the greatest attainable economy by Steam Jacketing, they must be supplied with Steam of a much higher temperature, and higher in proportion as the metal is thicker through which the heat must be transmitted.

should be taken to arrange these cocks or appliances, so that they may not be tampered with by being turned off, or on, to suit the fancy of a meddlesome engine-driver.

4. *The steam supply pipe should enter the Jacket at such a point that a thorough circulation of the steam within may be secured and maintained, and the accumulation of air at any part made impossible.*

5. *The working steam should not be made to traverse round the cylinder body ere it reaches the stop valve*, a plan which was constantly used in the earlier jacketed engines, and one which I trust may soon be totally abandoned, but I regret to say that there are several so-called celebrated makers of portable, and traction engines, who still cling to this old fashioned and objectionable practice, notwithstanding that in several works on the Steam Engine wherein the practice of steam jacketing is referred to, the authors have emphatically objected to this course. The Jacket is thus turned into a refrigerator, some of the steam is condensed in its passage, and the water resulting will be carried

into the cylinder, causing an effect similar to that produced were the jacket not used, or as one writer has said:—"It is objectionable to supply the jacket with steam which is on its way to the cylinder, the result being to condense the steam partially *before* instead of *during* expansion."*

6. *It is essential that the provisions made for the drainage of the jacket should be most efficient and complete;* to fully answer their end, they should be so planned that they continually operate, irrespective of any control from the attendant, indeed it should be impossible for his negligence or mischievous interference to hinder, or impair their action; for it is quite a simple matter to secure perfect drainage without any attention on the engine-driver's part. In many fixed engines, it is practicable to have the cylinder fixed at a sufficient elevation above the boiler, to admit of the jacket draining itself by gravitation, the pipe for this purpose entering the boiler below the water line; where this cannot be carried out, the drain pipe is sometimes connected to a steam trap.

* "Economy in the use of Steam," by Mr. Frank Salter.

Some readers may remember that this plan was adopted by Mr. Jeremiah Head for the drain pipes from the cylinder of his Patent Prime Mover; illustrations and description of this engine appeared in "Engineering" for 7th April, 1876. In portable engines, the bottom of the jacket should be inclined towards the steam supply from the boiler, and care should be taken to have no shelves in any part of the jacket, either top or bottom, where water may find a lodging place. Several engineers entertain an erroneous impression respecting the drainage of the jacket, they fancy that if the drain pipes are occasionally opened that will be sufficient. It must be distinctly understood that *no occasional blowing out will do*, the jacket condensation is continuous, hence the water resulting from this incessant cause should be got rid of as fast as it is formed.

Mr. Frank Salter, in his little work on "The Economy in the use of Steam," falls into error, where he says:—that the "condensed water" from the jacket "is blown out *occasionally*." It may be that this remark applies to present practice in some quarters yet it is none the less objectionable on that account.

7. *The working barrel of the cylinder should be made as thin as possible, and of the best conductor of heat.* "The thickness of the metal of the cylinder, that is, between the steam in the jacket and the internal surface of the cylinder, is of very great importance, because the transmission of heat, both in time and quantity, is inversely as the distance passed through, and therefore the shorter such distance, the more efficacious will be the steam in the jackets."*

It is a well known fact that many makers of portable engines cast the walls and partitions of their cylinders of such a thickness as to seriously interfere with the transfer of the heat from the jacket to the cylinder; these thick walls are introduced to lessen the risk from defective castings in the foundry, for the steam jacket and cylinder when made in one is a somewhat complicated and troublesome casting to make, as already mentioned at page 29. Herein consists one of the most valuable advantages of casting the cylinder and bush separately, the bush may be made as thin as possible, and as hard as practicable, reducing the wear to a minimum, so that repeated re-boring will not be

* "Hopkinson's Engineer's Guide."

necessary, and perhaps under some conditions re-boring may not be required at all.

This system of forming the jacket and bush separately, is now becoming more universal, consequently thin liners follow in its train. Steel liners are now being adopted for all classes of engines with success;* the working barrels of Mr. John Bourne's balanced, high pressure, high speed engines are made of this material, and are advertised as being "easily renewable."

Phosphor-bronze is now largely used for all manner of purposes, it would not only be in keeping with the spirit of the times to propose that liners of this material be used, but it has, likewise, several favourable properties to recommend it; for instance, it may be made as hard as desirable—it will take an excellent surface—while its conductivity is more than three times as great as that of cast iron.

* STEEL LINERS for cylinders were first used on Portable Engines by the Reading Iron Works Company. They are now used also in America for Corliss Engines of large dimensions. It is only recently that they have been applied to Marine Engines, the credit of their introduction is due to Mr. Allen, of Sunderland, who read a paper on this subject before the Institute of Engineers and Shipbuilders of Scotland, containing an interesting account of their successful application to several high pressure cylinders.

8. *In large engines of short stroke, not only should the covers be jacketed, but the piston should be heated,* for it is well known that the jacket round the barrel is powerless to extend "its influence right into a great body of steam;" and in these cases the covers and pistons expose a larger area of heating surface if fitted with steam than the circumferential jacket does. It has been said, "that the action of a steam jacket in securing economy is greater as the diameter of the cylinder is smaller."

9. With regard to jacketed cylinder covers, *the utmost care must be bestowed on their steam supply and drainage,* for nearly all the jacketed covers are defective in this matter. In the majority of cases these communications simply consist of a few holes drilled through the ends of the cylinder into the jacket, and similar holes to correspond, drilled opposite them in the faces of the covers; (as described from practice at page 18.)

There should always be some provision made for preventing these holes becoming choked up with red lead when the cover joint is being made, for unless this be attended to, they will

undoubtedly soon become obstructed; few engine-drivers would take the trouble to keep them clear, and no one could guarantee to always keep them them open no matter how carefully the joint was made. One very simple plan is to provide a plug opposite each communication hole, which may, before the joint is made, be taken out, and a bar or bolt passed through it into the communication hole at the time that the joint is being made. Red lead is thus prevented from entering the holes, and of obstructing the passage of both steam and water. To properly drain the jacketed covers of several types of engines is a somewhat difficult task. It is not my intention, however, at present to deal with the best means for overcoming these difficulties,* and for effectively getting rid of all condensed steam from them; to make the subject clear it would be necessary to refer to drawings of the covers used for the various engines.

10. There is room for improvement in most steam engines in the matter of the clearance,

* Various plans will be proposed in a work on Steam Jacketing now in preparation.

which should be reduced to a minimum, and the steam ports should be kept as short as possible.* It is owing to this feature in a great measure that the Corliss Engine has been so successful.

If practicable the exhaust and supply should be effected by means of separate ports, the one for the inlet being steam jacketed, for Mr. Joule has pointed out that the almost universal practice of making the steam enter and leave the cylinder by the same port tends to the waste of heat, especially with high rates of expansion.

Very few engines beside the Corliss have separate steam and exhaust ports.

11. *To get the best results from the use of the steam jacket, the working steam should be as dry as possible*, because all wet steam admitted into the cylinder is evaporated during the stroke by heat abstracted from the jacket. Mr. Northcott says in his work on "The Theory and Action of the Steam Engine" that owing to this cause, "it is not unusual to see engine diagrams in which the expansion curve rises considerably above even the hyperbolic curve. In all such cases the loss must be very considerable."

* By making the steam-chest longer than the cylinder the steam ports in most engines can be kept straight and very short.

12. The last but not least part of our duty is to emphatically denounce all steam jackets that are left exposed to the atmosphere or unlagged, indeed it should be, amid all our present knowledge, totally unnecessary to mention this, as one of the needful conditions of successful jacketing; but, much as I regret it, I am bound to confess that there are many engines turned out of hand with steam jacketed cylinders unlagged, chiefly on low-priced portable and vertical engines intended in not a few instances for out-door service. Need we wonder that some makers say that they have tried the jacket, and find very little difference in the coal consumption during the test of an engine with the cylinder steam jacketed and the surface of the jacket left totally exposed, and one with the cylinder unjacketed, but carefully clothed and lagged over the whole surface; for what is gained inside of the cylinder by the application of the steam jacket is partly counteracted by the loss of heat radiated from the unlagged jacket.*

* "Radiation of heat from the cylinder, and other parts of the engine, is a very direct source of loss. Some experiments made by Mr. D. K. Clark show that in the case of exposed cylinders the loss from this cause may rise to as much as 50 per cent. It is impossible to wholly prevent escape of heat; but by casing, or lagging, the

Happily these examples of second-rate engines are becoming every day more exceptional; the standard of efficiency is gradually being raised, hence steam jacketing combined with careful lagging is now more general than ever.

It is impossible to mention by name even the immense number of non-conducting compositions introduced for the purpose of preventing the radiation of heat from cylinders—steam pipes—boilers, &c. The importance of *careful clothing* of all *vessels containing high pressure steam* cannot be too strongly urged,* indeed it has been ascertained that the cost of covering a cylinder—pipes—and boiler with good composition will be saved by economy in fuel in a few months. Leroy's composition has been found

cylinder and steam pipes with a non-conducting material, the loss by radiation may be reduced to probably as little as 2 per cent." Mr. Northcott in "Theory and Action of the Steam Engine," page 91.

* Clothing it would appear is being carried to the utmost limit in some quarters. For instance, at the Royal Agricultural Society's Show held at Cardiff, in 1872, the *smoke-box* of one of the racing portable engines was actually coated with a lining of non-conducting composition, it would have been about as reasonable to have clothed the chimney in a similar manner, or to have bound a hay band round the safety-valve lever, and just as likely to conduce to economy. While at the Oxford Show of the same Society an engine was exhibited with a lagged crank-shaft.—"The Engineer," 19th July, 1872.

in practice to save 15 per cent., though in some cases there has been an economy of 20 per cent. in fuel in connection with marine engines. "It should be carefully borne in mind although it is constantly forgotten, that whether the protective material is or is not a first-rate non-conductor, unless its qualities as a non-radiator are also good it cannot prove wholly satisfactory."

By increasing the thickness of low conductors the loss of heat becomes rapidly less, but "with moderately good conductors the loss with all thicknesses is greater than by a naked cylinder and the thicker the casing the greater the loss." "As far as conduction goes there is nothing like an air space for retaining heat, when this cannot be adopted, cements or felts, &c. must be used."

We may imitate with advantage and profit an American example of effective cylinder clothing. I refer to the 1,400 horse-power Corliss engine at the late Philadelphia Exhibition. The cylinders were steam jacketed and covered with hair felting and lagging, the former $\frac{3}{4}$-in. thick, the latter 1-in. thick, outside this there was an air space $\frac{1}{2}$-in. thick between

it and the *polished* iron casing. The following sentence bearing on this subject is quoted from "Hopkinson's Guide." "To prevent the escape of heat by radiation, it is only necessary that the cylinder, and all parts of the metal which receive heat from the steam by contact or conduction, should have a clean metallic surface. Whoever has been much about steam engines will have often felt that a dirty cylinder, and engine generally, seemed to make the engine room insufferably hot. Such is really the fact. If any one should doubt the statement that a clean polished metallic surface radiates less heat than a black and dirty one, let him try the experiment, and he will doubt no more. Cleanliness therefore is the handmaid of economy, and at the same time, pleasant withal to look upon."

Section of Traction Engine Cylinder.

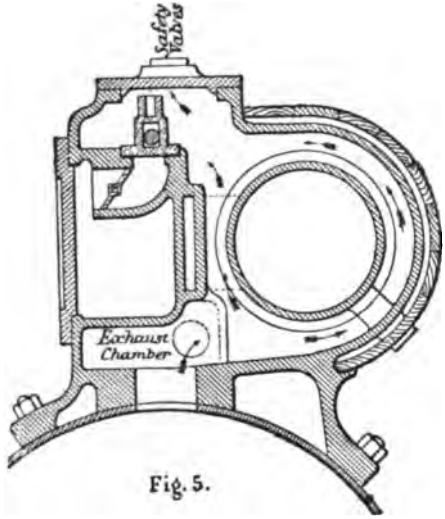


Fig. 5.

Section of Portable Engine Cylinder.

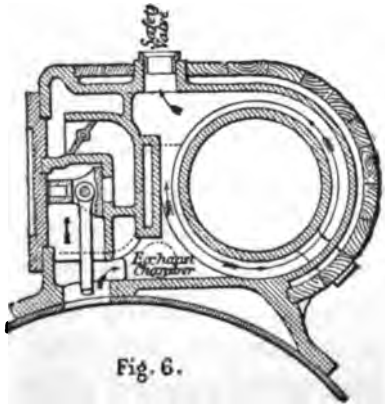


Fig. 6.

Description of two Steam Jacketed Cylinders from modern practice.

We have already given four illustrations representing sections of cylinders which were considered faulty in design, it may not be amiss to introduce two more sections of cylinders from recent practice, designed by the writer, which have been most carefully arranged and in which are embodied as many of the necessary requirements for rendering the steam jacket of the highest service that it is possible to apply to cylinders intended for these classes of engines.

Figure 5 represents a section through steam supply of an eight-horse power Agricultural Locomotive Engine Steam Jacketed Cylinder, while Figure 6 shows a section through steam supply of an eight-horse power Portable Engine Steam Jacketed Cylinder. Let us briefly name their principal characteristics. It will be seen that the jacket completely encircles the working cylinder, and that the exhaust steam is not permitted to come into contact with it. The exhaust chambers are clearly shewn in both figures with the exit pipe dotted in. The jacket is always open to and supplied with steam direct

from the boiler. The condensed steam will, as quickly as it is formed, run back into the boiler, the bottom of the casing being inclined towards the inlet from the boiler, it is impossible for either of these jackets to contain any water at any time; it is equally impossible for the engine-driver to tamper with the steam supply or the drainage, or by his neglect to frustrate the proper action of either. Two safety valves are provided on the top of the cylinder marked figure 5, and one on the top of figure 6, both jackets forming, in reality, part of the steam space of the boiler. The cylinder casing and the bush are separate castings, the bush is of hard metal of a medium and equal thickness all round, for the free passage of the heat from the jacket to the working steam. Both cylinders are clothed with felt and lagged with wood $\frac{3}{4}$ of an inch thick, then cased in with No. 8 B. W. G. sheet iron in the usual manner.

In conclusion—The object kept constantly in view while writing this exposure of the faults in the design and construction of the steam jacket, has been to shew one cause of a constant and considerable loss of steam or reckless waste

of fuel, so that all may as far as lies in their power reduce or prevent the waste arising from this source at least, for fuel saved is fuel gained; and if, therefore, by this effort some have been induced to minimise waste and consequently have increased the power developed from a given weight of fuel used, our aim has been accomplished.

FINIS.